Amendments to the Specification:

Please replace the Abstract with the following amended paragraph:

A fiber optic rotary joint is provided that is unaffected by variations in the optical properties of a fluid that fills its internal cavity. The rotary joint includes a housing defining the internal cavity, first and second optical collimation arrays on opposite sides of the internal cavity, and a reversion prism between the optical collimation arrays. Further, the rotary joint includes an interface optical element proximate at least one of the first and second optical collimation arrays and the reversion prism. Each interface optical element includes an optically-flat surface adapted to contact the fluid such that optical signals that are oriented normal to the optically-flat surface can be transmitted without refraction, thereby rendering the optical signals immune to variations in the fluid's optical properties. A reversion prism assembly, an optical collimation assembly and a method of aligning an optical collimation array utilizing alignment pins are also provided.

Please replace paragraph [0005] with the following amended paragraph:

[0005] A fiber optic rotary joint includes a housing that defines an internal cavity. The housing is adapted to engage end portions of two bundles of optical fibers, hereinafter referenced as the first and second bundles. As such, the first and second bundles of optical fibers are typically disposed on opposite sides of the internal cavity. By appropriately aligning the first and second bundles of optical fibers, respective pairs of the optical fibers of the first and second bundles can communicate across the internal cavity. In order to assist with this alignment and to facilitate communications between the first and second bundles of optical fibers, the fiber optic rotary joint includes a reversion prism. A reversion prism is a trapezoidal prism defining a longitudinal axis therethrough and having opposed end faces that are disposed at equal, but opposite, angles relative to the longitudinal axis. As such, optical signals emitted by an optical fiber of the first bundle are refracted by one angled end surface of the reversion prism, totally reflected from the longer base surface of the reversion prism, and then refracted again upon exiting from the other angled end surface of the reversion prism. If aligned properly, the optical signals exiting the reversion prism are received by a respective optical fiber of the second bundle. In order to facilitate this alignment and optical coupling of respective fibers of the first and second bundles, the reversion prism may be mounted upon a stage that permits the reversion prism to be controllably positioned. See, for example, U.S. Pat. No. 6,301,405.

Please replace paragraph [0014] with the following amended paragraph:

[0014] Each interface optical element includes an optically-flat surface adapted to contact the fluid that fills the internal cavity. The interface optical element is also adapted to permit optical signals that are oriented normal to the optically-flat surface to be transmitted between the fluid and the interface optical element. Since the optical signals enter and exit the interface optical element in a direction that is normal to the optically-flat surface of the interface optical element, the optical signals are not refracted and, as such, variations in the optical properties, including the index of refraction, of the fluid that fills the internal cavity of the fiber optic rotary joint do not affect the propagation of the optical signals. As such, the alignment of the first and second bundles of optical fibers is thereby maintained by the fiber optic rotary joint of the present invention as the optical properties of the fluid vary, such as in response to changes in the temperature and/or pressure to which the fiber optic rotary joint is exposed.

Please replace paragraph [0016] with the following amended paragraph:

[0016] In this aspect of the present invention, one interface optical element is disposed proximate a respective end surface of the reversion prism. The interface optical element is positioned such that the optically-flat surface is orthogonal to the longitudinal axis. Thus, the optical signals that enter and exit the reversion prism assembly are advantageously normal to the optically-flat surface of the interface optical element, thereby permitting the optical properties, including the index of refraction, of the fluid to vary without adversely affecting the propagation of the optical signals therethrough. Typically, the reversion prism assembly also includes a second interface optical element disposed

proximate the opposite end surface of the reversion prism such that the optical signals entering and exiting the reversion prism assembly from either end are immune to variations in the optical properties of the fluid. While the reversion prism and the interface optical element(s) may be formed of various materials, the reversion prism generally has an index of refraction that is greater than the index of refraction of the interface optical element.

Please replace paragraph [0017] with the following amended paragraph:

[0017] The interface optical element generally includes a mating surface that faces the respective end surface of the reversion prism. This mating surface is also advantageously disposed at the same nonorthogonal angle relative to the longitudinal axis as the respective end surface of the reversion prism. As such, the interface optical element may be a triangular prism which is designed such that the mating surface of the triangular prism is adhered to the respective end surface of the trapezoidal prism, while maintaining the optically-flat surface of the triangular prism in an orthogonal direction relative to the longitudinal axis.

Please replace paragraph [0018] with the following amended paragraph:

[0018] According to another aspect of the present invention, the interface optical element may be disposed proximate an optical collimation array to form a plurality of optical collimation assemblies. According to this embodiment, each optical collimation assembly may include an optical fiber and a collimating lens disposed in optical communication with the optical fiber. The collimating lens collimates the light transmitted and/or received by the optical fiber relative to a collimation optical axis defined by the collimating lens. Each optical collimation assembly of this embodiment also includes an interface optical element, such as a plane-parallel plate, disposed proximate the collimating lens. The interface optical element is oriented such that the optically-flat surface is orthogonal to the collimation optical axis.

Please replace paragraph [0019] with the following amended paragraph:

[0019] The optical collimation assembly may also include a sleeve in which the collimating lens and the interface optical element are disposed. The sleeve generally opens into a housing that is at least partially filled with the fluid such that the interface optical element is exposed to the fluid. Since the optically-flat surface of the interface optical element is orthogonal to the collimation optical axis, however, the optical signals enter and exit the interface optical element at an orientation that is normal to the optically-flat surface such that variations in the optical properties, including the index of refraction, of the fluid do not adversely affect the propagation of the optical signals therethrough. The optical collimation assembly may further include one or more index matching elements disposed within the sleeve, such as between an end portion of the optical fiber and the collimating lens and/or between the collimating lens and the interface optical element. The index matching elements prevent the fluid from residing in the optical path within the optical collimation assembly, such that variations in optical properties, including index of refraction, of the fluid do not adversely affect the

effective focal length for the collimating lens. Additionally, the index matching elements are included so as to reduce undesirable back reflections within the optical collimation assembly.

Please replace paragraph [0024] with the following amended paragraph:

[0024] Accordingly, an improved fiber optic rotary joint is provided according to one embodiment of the present invention that maintains the alignment of first and second bundles of optical fibers as the optical properties, including the index of refraction, of the fluid that fills the fiber optic rotary joint varies in response to temperature and/or pressure changes. In this regard, a reversion prism assembly and/or an optical collimation assembly may be provided in which interface optical element(s) are disposed proximate the reversion prism and the collimating lens, respectively, in order to provide an optically-flat surface through which signals enter and exit with an orthogonal orientation so as not to be refracted by the fluid disposed within the internal cavity of a fiber optic rotary joint. According to another aspect of the present invention, an improved method of aligning an optical collimation array such that the plurality of collimation assemblies including the plurality of optical fibers are commonly oriented to be parallel to the physical axis of the optical collimation array, thereby also improving the alignment of the bundles of optical fibers optically interconnected by a fiber optic rotary joint.

Please replace paragraph [0034] with the following amended paragraph:

[0034] The fiber optic rotary joint 10 also includes first and second optical collimation arrays 20. The first and second optical collimation arrays are disposed in respective passages defined by the housing 16 that open into the internal cavity 18. As shown, the first and second optical collimation arrays are generally positioned on opposite sides of the internal cavity for transmitting optical signals therethrough. While the optical collimation arrays may each have only a single element, in which case the fiber optic rotary joint would be a single channel fiber optic rotary joint, the optical collimation arrays typically include a plurality of elements such that the fiber optic rotary joint is a multi-channel fiber optic rotary joint. As such, a fiber optic rotary joint will be subsequently described in conjunction with first and second optical collimation arrays that <u>have</u> ~~has~~ multiple elements for purposes of example, but not of limitation.

Please replace paragraph [0035] with the following amended paragraph:

[0035] One or both of the optical collimation arrays 20 may be rotatably mounted to the housing 16 such that one optical collimation array may rotate about its respective longitudinal axis relative to the other optical collimation array. In the embodiment illustrated in FIG. 1, for example, both optical collimation arrays are rotatably mounted within the housing. However, even in this embodiment, one of the optical collimation arrays may be ~~affixed~~ <u>fixed</u>, such as by engaging the portion of the optical collimation array that extends external to the housing, so as to prevent the respective optical collimation array from rotating, if desired.

Please replace paragraph [0036] with the following amended paragraph:

[0036] The fiber optic rotary joint 10 also includes a reversion prism 22 disposed within the internal cavity 18 between the first and the second optical collimation arrays 20. The optical signals transmitted between the optical collimation arrays therefore pass through the reversion prism, which maintains the alignment between respective optical fibers of the first and second optical collimation arrays as at least one of the optical collimation arrays rotates about its longitudinal axis relative to the other. As known to those skilled in the art, the housing 16 and, in particular, the reversion prism, may also be rotated at a rate that is 50% of the rate at which the optical collimation assembly rotates. By rotating the housing and, in particular, the reversion prism in this manner, the fiber optic rotary joint maintains optical communication between the same respective pairs of optical fibers of the first and second optical collimation arrays even as the optical collimation array rotates.

Please replace paragraph [0037] with the following amended paragraph:

[0037] As shown in FIG. 1, the housing 16 may include a removable cover 24 that may be secured to the remainder of the housing by bolts 26 or other connectors. By removing the cover, access to the internal cavity 18 and the reversion prism 22 is provided. To facilitate precise positioning of the reversion prism, the reversion prism may be mounted upon a stage 28, such as that described in detail by U.S. Pat. No. 6,301,405. The stage facilitates the positioning of the reversion prism in at least three directions. In this regard, the base portion 30 of the stage may define a groove for receiving a corresponding pin 32 that extends upwardly beyond the surface of the base portion such that the reversion prism at least partially rests upon the pin. Additionally, a set screw 34 can extend through the base portion. As such, by advancing or retracting the set screw, the position of the reversion prism may be adjusted, such as to pivot on the pin 32 as depicted in the embodiment of FIG. 1. In order to permit access to the set screw, the housing can define an opening aligned with the set screw. Once the reversion prism has been properly positioned, however, a plug 36 may be disposed within the opening such that fluid may be retained within the internal cavity. Additionally, at least one of the ~~sidewalls~~ side walls (not shown) of the stage may also define a groove and receive a corresponding pin that protrudes outwardly beyond the respective side wall for contacting a side surface of the reversion prism. Another set screw can extend through the respective side wall such that the position of the reversion prism can be adjusted in another direction, such as to pivot on the pin into and out of the page in the embodiment depicted in FIG. 1, by advancing or retracting the set screw. Again, the housing may define an opening aligned with the set screw to provide access to the set screw and, once the reversion prism is properly positioned, a plug may be disposed within the respective opening. Additionally, a guidepost integrally attached to the base portion of the stage 28 is supported on the end of a set screw (not shown). As such, by advancing or retracting the set screw, the position of the stage, and as a result the reversion prism, may be adjusted, such as in a vertical direction as depicted in the embodiment of FIG. 1.

Please replace paragraph [0039] with the following amended paragraph:

[0039] According to the present invention, the fiber optic rotary joint 10 also includes one or more interface optical elements. As described in detail below, the interface optical elements may be disposed proximate to one or both of the first and second optical collimation arrays 20 and/or proximate the reversion prism 22. The interface optical element includes an optically-flat surface 48 that is adapted to contact the fluid. As known to those skilled in the art, an optically-flat surface introduces optical distortions that are small relative to the wavelength of the optical signals. Thus, optical signals may be transmitted between the interface optical element and the fluid that fills the internal cavity 18 of the housing 16 in an orientation that is normal to the optically-flat surface without causing the optical signals to refract. As such, variations in the optical properties of the fluid, such as variations in the index of refraction of the fluid, will not alter the manner in which the optical signals propagate and, as such, will not disadvantageously alter the alignment of the respective optical fibers of the first and second optical collimation arrays.

Please replace paragraph [0040] with the following amended paragraph:

[0040] In one aspect of the invention, a reversion prism assembly is provided that not only includes the reversion prism 22, but also at least one interface optical element 40 disposed proximate thereto. As shown in FIG. 1 and in somewhat more detail in FIG. 2, the reversion prism assembly includes a reversion prism extending longitudinally between opposed end surfaces 42, 42 and defining a longitudinal axis 44 that extends through the opposed end surfaces. The opposed end surfaces are disposed at a non-orthogonal angle relative to the longitudinal axis. In this regard, the opposed end surfaces generally define an equal, but opposite angle, such as 45°, relative to the longitudinal axis. As such, the reversion prism is typically a trapezoidal prism. While the reversion prism may be formed of various materials, the reversion prism of one embodiment is formed of a glass having a relatively high index of refraction, such as LASFN9 glass having an index of refraction of about 1.85.

Please replace paragraph [0041] with the following amended paragraph:

[0041] The reversion prism assembly of this aspect of the present invention also includes at least one interface optical element 40 disposed proximate a respective end surface 42 of the reversion prism 22. In this regard, the interface optical element generally includes a mating surface 46 that is attached to the respective end surface of the reversion prism, such as by means of an optically-transparent epoxy. In this regard, the mating surface is generally disposed at the same non-orthogonal angle to the longitudinal axis 44 as the respective end surface of the reversion prism. In addition to the mating surface, the interface optical element includes the optically-flat surface 48 through which optical signals enter and exit the reversion prism assembly. According to this aspect of the present invention, the optically-flat surface is disposed orthogonally to the longitudinal axis defined by the reversion prism. Thus, the interface optical element may be a triangular prism that is adhered to the respective end surface of the trapezoidal reversion prism. The interface optical element of this embodiment may be formed of various materials, but generally is formed of a glass having an index of refraction that is somewhat lower than that of the reversion prism. For example,

the interface optical element may be formed of BK7 glass having an index of refraction of about 1.5. By increasing the difference between the indices of refraction of the reversion prism and the interface optical element, the size, i.e., the length as measured along the longitudinal axis, of the reversion prism assembly is reduced, which advantageously facilitates the incorporation of the reversion prism assembly in a smaller housing.

Please replace paragraph [0042] with the following amended paragraph:

[0042] By providing an optically-flat surface 48 through which optical signals propagate in an orthogonal, i.e., normal, orientation, changes in the index of refraction of the fluid, such as those created by variations in the temperature and/or pressure to which the fiber optic rotary joint is exposed, do not affect the propagation of the optical signals since the optical signals are not refracted at the interface of the optically-flat surface of the interface optical element 40 and the fluid. Thus, the optical alignment of respective optical fibers of the first and second optical collimation arrays 20 is maintained. In order to facilitate the propagation of optical signals through the optically-flat surface of the interface optical element, the optically-flat surface may be coated with an anti-reflection coating, if desired.

Please replace paragraph [0043] with the following amended paragraph:

[0043] As shown in FIGS. 1 and 2, the reversion prism assembly may include a second interface optical element 40 disposed proximate to the other end surface 42 of the reversion prism 22. In this regard, the second interface element may also have a mating surface 46 that is adhered to the other end surface 42 of the reversion prism. As before, the mating surface of the second interface optical element is also advantageously disposed at the same non-orthogonal angle relative to the longitudinal axis 44 as the respective end surface of the reversion prism. As such, the optically-flat surface ~~46~~ 48 of the second interface optical element is disposed orthogonal to the longitudinal axis of the reversion prism in order to facilitate the propagation of optical signals therethrough in a direction normal to the optically-flat surface. The optically-flat surface of the second interface optical element may also be coated with an anti-reflection coating, if desired.

Please replace paragraph [0044] with the following amended paragraph:

[0044] As such, optical signals may propagate through a reversion prism assembly of one embodiment of the present invention as depicted in FIG. 2. As shown, optical signals enter through the optically-flat surface 48 ~~46~~ of one of the interface optical elements 40. Since the optical signals enter in a direction that is normal to the optically-flat surface, the optical signals are advantageously not refracted at the interface between the surrounding fluid and the interface optical element. The optical signals are refracted, however, by the interface between the interface optical element and the reversion prism 22 due to the difference in the respective indices of refraction. The optical signals reflect from the base portion 52 of the reversion prism. In order to facilitate the reflection from the base portion of the reversion prism, the base portion may have a reflection coating. After the

reflection from the base portion, the optical signals are again refracted by the interface between the other end surface of the reversion prism and the other interface optical element so as to again be directed normal to the optically-flat surface of the other interface optical element. Thus, changes in the index of refraction of the fluid that fills the internal cavity of the fiber optic rotary joint do not alter the propagation of the optical signals such that the optical signals can continue to be coupled between respective optical fibers of the first and second optical collimation arrays.

Please replace paragraph [0045] with the following amended paragraph:

[0045] According to another aspect of the present invention, an optical collimation assembly 54 is provided in instances in which the interface optical element 56 is disposed proximate one or both of the optical collimation arrays 20, either instead of or, most typically, in addition to being disposed proximate the reversion prism 22. As shown in FIG. 1 and in somewhat more detail in FIG. 3, the optical collimation assembly includes an optical fiber 55 ~~56~~ and a collimating lens 58 disposed in optical communication with the optical fiber. Thus, the optical signals emitted or received by the optical fiber are collimated by the collimating lens along a predefined collimation optical axis 60. An end portion of the optical fiber is commonly disposed within a ferrule 62, such as a ceramic ferrule of the type utilized by conventional fiber optic connectors. In addition, while various types of collimating lenses may be utilized, a ball lens serves to collimate the optical signals in one embodiment. In addition, while the collimating lens may be formed of various materials, the collimating lens is formed of LASFN9 glass having an index of refraction of about 1.85 in one embodiment. The optical collimation assembly may also include a sleeve 64 in which the collimating lens as well as the end portion of the optical fiber are disposed. In this regard, the sleeve may be sized such that the inner diameter of the sleeve is approximately equal to the diameter of the collimating lens and the ferrule in which the end portion of the optical fiber may be disposed, such as 2.5 mm in one embodiment, such that the collimating lens and the ferrule are snugly received therewithin. Alternatively, the sleeve may be sized to define an inner diameter that is slightly smaller than the components to be disposed therein. However, the sleeve of this embodiment may define a lengthwise-extending slit to permit the sleeve to open further to accept the components and to hold the components snugly therein. The sleeve may be formed of various materials, but is formed of a ceramic material in one embodiment. By snugly receiving and holding the collimating lens and the ferrule, the sleeve advantageously maintains optical alignment of the optical fiber and the collimating lens as is desired maintaining a relatively low insertion loss.

Please replace paragraph [0046] with the following amended paragraph:

[0046] According to this aspect of the present invention, the optical collimation assembly 54 also includes the interface optical element 56. The interface optical element is disposed proximate the collimating lens 58. In the embodiment in which the optical collimation assembly includes a sleeve 64, the interface optical element is also generally disposed within the sleeve on the opposite side of the collimating lens from the optical fiber 55 ~~56~~. As shown in FIG. 3, for example, the interface optical element of this embodiment may be a plane-parallel plate that serves as a cylindrical window

that is disposed within one end of the sleeve. The interface optical element and the sleeve are preferably sized such that the interface optical element is snugly received within the sleeve and is accordingly aligned with the optical fiber and the collimating lens. The interface optical element may be adhered to the inner surface of the sleeve.

Please replace paragraph [0047] with the following amended paragraph:

[0047] The interface optical element 56 includes the optically-flat surface 66 as described above. The optically-flat surface of the interface optical element of this embodiment is oriented orthogonally to the collimation optical axis 60. Thus, optical signals are transmitted between the interface optical element and the internal cavity of the housing, and, more commonly, the fluid disposed within the internal cavity 18 of the housing 16 in a direction that is normal to the optically-flat surface of the interface optical element. As such, the optical signals are not refracted at the interface of the interface optical element and the fluid such that variations in the optical properties of the fluid, such as the index of refraction of the fluid, do not disadvantageously alter the propagation of the optical signals.

Please replace paragraph [0049] with the following amended paragraph:

[0049] In order to transmit optical signals, the optical signals emitted by the optical fiber 55 ~~56~~ are collimated by the collimating lens 58 and then passed through the interface optical element 56 at an orientation that is normal to the optically-flat surface 66. As such, variations in the index of refraction of the fluid to which the interface optical element is exposed will not alter the propagation of the optical signals since the optical signals are not refracted at the optically-flat surface. Conversely, optical signals received by the optical collimation assembly 54 arrive with an orientation normal to the optically-flat surface of the interface optical element. These optical signals are focused by the collimating lens to the optical fiber. Since the fluid no longer contacts the collimating lens or other components of the optical collimation assembly, optical signals can be reliably transmitted to and from the optical fiber even as the optical properties of the fluid disposed within the housing of the fiber optic rotary joint vary.

Please replace paragraph [0050] with the following amended paragraph:

[0050] The first and second optical collimation arrays 20 may each be formed of a plurality of optical collimation assemblies 54 as described above and as depicted in FIG. 3. In this regard, a plurality of optical collimation assemblies may be disposed within an outer sleeve 70 that, in turn, is mounted to the housing 16, such as by means of a rotational engagement as shown in FIG. 1. As shown in FIGS. 4a and 4b, by way of example, the plurality of optical collimation assemblies can be disposed in various configurations to comprise a respective optical collimation array. As shown in FIG. 4a, for example, a plurality of optical collimation assemblies, such as seven optical collimation assemblies in the illustrated embodiment, may be relatively tightly packed within the outer sleeve. In order to construct optical collimation arrays having more optical fibers, optical collimation arrays

having larger outer sleeves with different internal configurations may be utilized. As shown in FIG. 4b, for example, an inner sleeve 72 may be disposed about a central optical collimation assembly with eleven optical collimation assemblies disposed peripherally about the inner sleeve which are, in turn, surrounded by the outer sleeve. While two configurations of an optical collimation array are provided by FIGS. 4a and 4b, the optical collimation arrays of the fiber optic rotary joint 10 of the present invention may have a number of other configurations, if so desired.

Please replace paragraph [0053] with the following amended paragraph:

[0053] According to one embodiment, the fiber optic rotary joint 10 therefore includes interface optical elements proximate both opposed end surfaces 42, 42 of the reversion prism 22 and proximate each collimating lens 58 of the first and second optical collimation arrays 20. As such, the optical signals that enter and exit the fluid that fills the internal cavity 18 of the housing 16 pass through the optically-flat surface of a respective interface optical element in a direction normal to the optically-flat surface such that the optical signals are not refracted. As such, variations in the optical properties of the fluid, such as variations in the index of refraction of the fluid, do not affect the propagation of the optical signals. Accordingly, the temperature and/or pressure to which the fiber optic rotary joint is exposed may vary without adversely affecting the alignment of the optical fibers of the first and second bundles 12,14 of optical fibers.